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M483 PROJECTILE SHORT TERM STICKER INVESTIGATION

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6 July 1975

PICATINNY ARSENAL

INTERIM STATUS REPORT
ON THE
M483 PROJECTILE SHORT TERM
STICKER INVESTIGATION

AMMUNITION DEVELOPMENT
AND
ENGINEERING DIRECTORATE

JULY 1975

INTERIM STATUS REPORT

ON THE

M483 PROJECTILE SHORT TERM

STICKER INVESTIGATION

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M483 Projectile Investigation

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The Status Report that follows covers the work performed in support of the M483 projectile short term sticker investigation.

It was presented to Col. Thomas, Chief of Staff, ARMCOM, 18 June; Major General G. Sammet, Jr., Deputy Commanding General for Materiel Acquisition, AMC, 2 July; and Major General L. E. Van Buskirk, Director of Combat Support Systems, DA, 3 July 1975, by Mr. R. Corn.

Report

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(Figure 1) The Purpose of this briefing is to present an overview of the 155mm sticker problem. I will cover the background in terms of sticker occurrences during testing of experimental and standard projectiles. I will further review the short term program which is underway at Picatinny Arsenal and is primarily directed toward the M483 projectile problem. I will discuss test results obtained in that program to date and provide interim conclusions. I will then discuss our proposed long term program which would cover the entire 155mm system sticker problem along with appropriate conclusions and recommendations.

(Figure 2) Stickers are characterized by failure of a projectile to move more than 1 inch in the tube before decelerating and stopping.

(Figure 3) A sticker can be cleared safely by following instructions in the TM for the M109A1 Howitzer. It is usually necessary to fire at a higher zone charge to expel the projectile. It should be pointed out that if a stuck projectile is allowed to remain for extended periods of time in a hot tube a safety hazard could result as a result of cook-off.

(Figure 4) Figure 4 presents a summary of sticker history which have occurred in engineering and service or DTII tests. We have had two people from Picatinny Arsenal spending about three weeks going through the available literature which is primarily in the form of firing records and test reports at the Aberdeen Proving Ground library. The only recorded sticker in the M109 Howitzer system occurred at Zone 1 with an M107 projectile during service tests of the XM483. Stickers have been reported with much more considerable frequency in testing of the M109A1 Howitzer. The figure illustrates the results reported in the service tests with a shallow forcing cone M109A1 which produced a high frequency of stickers at Zones 1 and 2 with the M107 projectile. During the test a steep forcing cone weapon was introduced with stickers only occurring at Zone 1. It was from these two tests that the frequently quoted figure of a 1% sticker rate at Zone 1 originated. Since that time there have been stickers with the M483 family of projectiles (XM692, XM687) at Zones 1, 2 and 3.

(Figure 5) This figure summarizes sticker history for standardized systems. It should be stated that in the IPT of the M109A1 a higher frequency of stickers had been obtained than was reported in the ET/ST with the sticker rate going as high as 50% in one group of 10 projectiles. These charts do not, of course cover all firings that have been conducted with the M107 projectile but only those where reports of stickers exist. They are, however, useful in demonstrating the point that sticker rates appear to be highly variable and are probably very much a function of weapon conditions, e.g., coppering, temperature, tube life, etc.

One of the reasons for the increase in reported stickers with the M109A1 system is shown in Figure 6. It can be seen that because of the larger chamber volume of the M109A1 weapon operating pressures have been significantly reduced and, in fact, it is not until Zone 3 that the chamber pressure in the M109A1 reaches the Zone 1 pressure of the M109. Therefore, 155mm projectiles which had been tested up until 1968-69 time frame were fired largely in the M109 system. There was relatively little data on how these projectiles would perform under the chamber conditions of the M109A1 at the lower zones.

(Figure 7) Another reason for the increase in reported stickers is clearly illustrated in Figure 7. As new projectiles were developed rotating bands were designed to perform at the higher velocities and spin rates of the Howitzer gun systems. It was known as early as the mid-60's that the M107 rotating band configuration was inadequate and, in fact, band shear was obtained when the M107 was fired at extreme conditions. As a result the newer 155mm projectiles such as the M483 and M549 have wider rotating bands and, in fact, the M483 also incorporates an obturating lip on the rotating band. These configurations, while substantially improving performance at the high zones, are much more likely to produce stickers at the low zones.

(Figure 8) I would like to discuss the specific incident involving the two 687 projectile Zone 3 stickers at Dugway Proving Ground. It was these stickers that led directly to the decision to produce only 10,000 M483 projectiles and caused initiation of the short term M483 sticker investigation which I will discuss later in the briefing. As can be seen from Figure 8, more than 200 XM687 projectiles had been fired at Zone 3. These projectiles were fired from 16 Nov 74 to 19 Feb 75 and, interestingly enough, the two Zone 3 stickers that did occur occurred on the same day on two consecutive rounds.

(Figure 9) Figure 9 indicates the round by round data for 19 Feb 75 when the two Zone 3 stickers occurred. The pressures required to expel the two stickers are also indicated. An unusual factor in these tests is the high chamber pressure recorded, M3A1 and XM164 charges, on that particular day. The pressures of the normal rounds are approximately 9000 psi which is about 10% higher than the previous Zone 3 tests. I will have more to say on this subject later in the briefing. It should be noted that the pressures in excess of 11,000 psi which occurred on the two stickers is the calculated closed bomb pressure of the charge at these conditions. That pressure remains in the chamber until the round is expelled.

(Figure 10) As a result of the XM687 stickers a short term program was initiated and funded by the Project Manager for Selected Ammunition with the objectives of determining those conditions which produce the highest frequency of stickers, obtaining performance data of the M483 and M107 at those conditions, and evaluating modifications designed to eliminate or reduce the sticker rate. In addition, mathematical modeling of the interior ballistic parameters was started immediately in an attempt to evaluate the sensitivity of projectile motion to various system parameters.

(Figure 11) A fault tree was constructed upon which the short term program was based. The figure shows the top of the fault tree and is, therefore, rather basic. However, it does show that a projectile can fail to exit the tube either because of high forces resisting projectile motion or because of improper propellant burning. Since the XM687 sticker problem, a number of stickers have been obtained during Picatinny testing. There is no evidence of improper burning of the propellant based on analysis of the pressure time data obtained. This is not to say, however, that a faster burning, high pressure charge is not a possible solution to a sticker problem but only that the M3 and XM164 charges appear to have functioned normally in the sticker instances that have occurred. The sticker appears to result from high resistive forces which can be obtained for a variety of reasons.

(Figure 12) The factors affecting stickers are shown in Figure 12. As indicated, a few will be addressed in the short term program but most are more appropriate for a longer term investigation. The area being covered in the short term program are being addressed primarily in terms of M483 projectile performance. Many of the factors involve a considerably longer term effort. We are proposing to explore them in a three year program which will cover the entire 155mm system.

(Figure 13) Figure 13 shows the current schedule for the M483 short term program as well as some of the projectiles and parameters we will be looking at. Funding has been made available for this effort by the Project Manager for Selected Ammunition with the cooperation of the agencies shown in Figure 14. Picatinny has been managing the program performing instrumented interior ballistic test firings. Watervliet has been running push tests of various projectiles in actual gun tubes and BRL has been doing push testing and modeling.

When the Dugway Zone 3 sticker first occurred a test firing program was immediately launched at Picatinny with M185 tubes which were available at the Arsenal at the time.

(Figure 15) The first tube used was a new ungrooved tube Serial No. 22657. Firings were begun at Zone 1 with the anticipation of a relatively high sticker rate based on prior experience with both the 483 family and the M107 family. In fact, it took 69 rounds of shooting at Zone 1 to produce a sticker. It should be pointed out that during these firings many things were done in an attempt to induce stickers including soaked prop charges, improperly rammed projectiles and charges loaded backwards into the chamber. No stickers were obtained with the above methods. Only 4 projectiles were fired at Zone 3 with no stickers obtained there either. After the first sticker was obtained in Tube 22657 the tube was shipped to Watervliet Arsenal for extraction of the projectile and examination of both the weapon and projectile and another tube (21982) was readied for firing at Picatinny.

In 1974 M109A1 weapons in the field were grooved in the origin of rifling area as a result of a fall back problem which occurred in Europe. Tube 22657 had not been grooved. Therefore a Watervliet representative was asked to groove 21982 before firing was begun in that tube.

(Figure 15) As can be seen from Figure 15 the first two M483 projectiles fired at Zone 1 both stuck. Two M107 projectiles were then fired with one of them sticking. More than 50% of the M483 fired at Zone 2 stuck and one of eight M483 projectiles fired at Zone 3 with the XM164 charge stuck. It should not be inferred necessarily from these tests that the difference in performance in tubes was a result of grooving because wide variations in sticker rates have occurred between apparently identical tubes during previous tests of the M109A1. It should also be noted that tube 21982 was mounted in an 8" tube on a 155mm gun mount and can not be considered a standard weapon system.

Immediately after the Zone 3 sticker, tube 21982 was shipped to Watervliet where the projectile was extracted and push tests run on that tube.

(Figure 16) Figure 16 shows the results of the Watervliet push testing on both of the tubes just discussed. It can be seen that grooving increased push forces by 20 - 30%. In terms of pressure this is equivalent to about one full Zone and could have perhaps pushed the sticker problem up by one zone. I would like to emphasize that grooving disappears after a few hundred rounds are fired from the weapon so its effects probably only apply to recently grooved tubes. Currently all tubes manufactured are being grooved. Data indicates that as the grooves wear out heat checking occurs which is sufficient to prevent fall back.

Now that we have produced stickers with the M483 we are beginning to look at possible system modifications. It is important to bear in mind that the modifications were directed toward a quick fix for any sticker problem that might arise with the 483 during compatibility testing with the M109A1 which is scheduled to begin in June.

(Figure 17) The short term fixes shown in Figure 17 were the only two that could reliably be incorporated and, in fact, a volume reducer which adds a significant logistic burden to the user while practical from a short term point of view is impractical from the point of view of user acceptance. A new low zone charge would require several months to develop and any band modification which might ease the sticker problem would have to be checked out through extensive testing especially at high zones in worn tubes to determine effects of band modification on band shear and muzzle velocity uniformity. This type of testing would require several months and is therefore considered impractical in terms of a short term fix.

(Figure 18) During the short term program tests were run with volume reducers and modified prop charges which significantly changed the pressure-time curve as shown in Figure 18. One of our goals in the short term program is to get a working mathematical model of the prop charge projectile relationship so that we can determine whether the improved curves will solve this problem.

(Figure 19) Figure 19 is a picture of an accelerometer of the type which is being used on-board at Picatinny Arsenal in a series of fully instrumented firings. Although the technology has been available for several years this is the first time a series of accelerometer firings have been used to obtain interior ballistic information. The accelerometer is mounted in a collector cup and packed in foam rubber as shown in Figure 20.

(Figure 21) Figure 21 shows the assembly mounted to the ogive of an M483 projectile. When the projectile is rammed the wire is run out the front of the tube to data recording equipment. As the projectile moves down the tube the wire is collected in the collector cup.

The type of data obtained is shown in Figure 22. This data is for a 483 family projectile fired at Zone 1 and is displayed as a function of distance in the tube. The velocity curve shown is derived by integrating the acceleration data obtained from the accelerometer, the thrust curve is derived from pressure time information which is obtained with piezo electric gages, and the resistance curve is derived by taking the difference between thrust forces and the force producing projectile motion as calculated from accelerometer data. As can be seen from this curve the thrust and resistance curves are very close and the resistance seems to peak in the area of the obturating lip on the rotating band. If the resistance curve should significantly rise above the thrust curve a sticker will result.

(Figure 23) Figure 23 represents an actual M483 Zone 1 sticker. As can be seen the resistance has risen to about 250,000 pounds and there is simply insufficient thrust to allow the projectile motion to continue.

A number of different rounds have been fired with on-board accelerometers and a great many resistance travel curves have been obtained.

(Figure 24) Figure 24 shows some typical band resistance curves which clearly show the variability of resistance of several projectiles. The highest resistance is obtained with an M483 sticker and the typical curve for a near sticker can clearly be seen. The M483 (teflon) curve represents that for an M483 with a teflon ring placed in the rotating band cannalure. The ring can be applied by simply stretching it over the projectile and slipping it into place in the cannalure. As can be seen from the chart this ring would act as a lubricant reducing the 483 resistance. The reduction in resistance is not as radical as the M483 with a modified band, the band modification consisted of removing the 6.289 diameter lip from the rotating band, but I would like to point out again that such a modification would require extensive testing especially at top zones in worn tubes. In addition testing at intermediate zones to determine effect on muzzle velocity which might necessitate a revised firing table would also have to be performed.

(Figure 25) Some velocity distance curves are shown in Figure 25 and I would like to point out that on this curve you can see what we call a "near sticker", where the projectile motion has stopped about 3/4" in the tube and then restarts as a result of a build up of thrust behind the stuck projectile. The first round or crash effect at low zones and creep may be very simply related to the difference in projectile resistance which we are for the first time obtaining detailed measurements on. The velocity data you are seeing may provide the foundation for solving some of these age-old problems.

(Figure 26) Figure 26 summarizes the results to date of the short term M483 sticker investigation. As can be seen, sticker rates are much higher at cold temperatures (both charge and projectile) and continue to vary from tube to tube although both tubes are grooved. Teflon significantly lowers the sticker rate at all zones and 108 rounds have been fired with teflon rings at -40° M3A1 Zone 3 without a sticker.

The summary and conclusions at this time for the short term program are summarized in Figure 27. First, based on analysis of the resistance curves the 483 projectile does have a higher resistance to motion than the M107. Secondly, the use of a solid lubricant in the form of a teflon ring has substantially reduced sticker rates with no stickers being obtained at Zone 3 and stickers obtained at Zone 2 only at -65° F. The short term program is, of course, continuing and will further address the factors indicated on Figure 12.

I would like to spend a few minutes discussing the 155mm stockpile, Figure 28, since it relates to the long term program I will be proposing. None of the projectiles in the stockpile had been tested at low zones as extensively as the M107 or the M483. For example, in the engineering and service tests of the M109A1 weapon the only projectile tested at Zone 1 was the M107 because TECOM made the assumption that the other rounds in the stockpile would perform similarly. Testing of the rest of the stockpile at Zones 1 and 2 has been very sparse and there is no information available with regard to performance at the low temperatures, which we are finding tend to increase the sticker rates. It is therefore important to determine whether the other rounds in the stockpile, many of which incidently, have different rotating band configurations and physical properties in the rotating band area, tend to stick at Zones higher than 1. For example, the M449A1 which is the first generation ICM projectile was designed to be highly rigid in the rotating band area to prevent collapse of the shell metal parts into the cargo area. There is, in fact, a rigid steel support plate under the rotating band. Push tests of this round conducted in the late 60's have indicated that the M449A1 was the most difficult of all the projectiles to push through the tube and, therefore, may have very high resistance forces during firing. It is critical, if the user finds the current sticker situation unacceptable, to evaluate the stockpile of 155mm ammunition as well as some of the developmental rounds and weapons to determine the effect on the overall sticker problem. A three-year program has been considered as shown in Figure 29. The first year of the program will primarily be directed at the sticker frequency of the stockpile. Proving ground tests of the M109A1 weapon will be continued to obtain statistical sample size for each of the rounds in the stockpile as well as on board accelerometer firings at Picatinny Arsenal to obtain precise interior ballistic information. At the same time a modeling and analysis program will continue which will attempt to provide an accurate prediction model for stickers. On board accelerometer firings will also be done in the 198 system which has a shallow forcing cone. By the end of the third year specific correction actions will be made for the stockpile with enough testing having been completed to provide assurance that the modifications proposed will correct the sticker problem. The program presented assumes that it is desirable to address the entire stockpile. It would, of course, be desirable to determine in advance whether it is worth the cost to provide a solution for all projectiles in the stockpile.

Figure 30 shows the proposed preliminary use of funds in the three years. The on board accelerometer program including the firings, the data reduction and the analysis will continue at Picatinny as well as the overall program, program coordination and management. Picatinny will work closely with BRL in the interior ballistic modeling area. The effort at Watervliet will be primarily involved in actual push tests of projectiles, both standard and modified, through tubes. We hope to be able to evaluate factors such as tube wear and coppering in this manner. Rock Island Arsenal has been doing intensive work in the projectile ramming and has a model for ramming forces required for adequate seating of projectiles. It is our goal to supplement the interior ballistic model with the Rodman Labs ramming model, since some preliminary data being obtained to date indicates that ramming has an extensive effect on initial projectile motion. Frankford Arsenal will be deeply involved with projectile modifications and redesign while TECOM will be conducting a good many tests with the standard stockpile projectiles. Battelle Institute will continue the work they are currently doing for us in tests of characteristic service materials in the tube.

Figure 31 indicates the effort that will be conducted during the first year. It is expected that this program will provide benefits which will clearly increase our knowledge of interior ballistics.

In summary then, (Figure 32) stickers are a complex system problem involving the projectile, propellant, and the weapon. The extent of that problem is not known with many stockpile projectiles but the on-board accelerometer technique does provide accurate interior ballistic information which can shed light on not only the sticker problem but on interior ballistics in general. Age-old problems, such as creep, crash and velocity may depend largely on resistive loads in the tube, and we are now in the short term program starting to obtain instrumented data which is contributing to our understanding of in tube motion.

It is therefore recommended (Figure 33) that the short term 483 sticker investigation continue and it is being continued with available funding. A long term program should be immediately initiated to address the stockpile problem and provide the options for corrective action. This program will also provide information which is necessary to enable the user to come u with an intelligent set of requirements with regard to the sticker probl .

OUTLINE

- BACKGROUND
- SHORT TERM PROGRAM
  - OBJECTIVES
  - CURRENT RESULTS
  - INTERIM SUMMARY/CONCLUSIONS
- PROPOSED LONG TERM PROGRAM
- SUMMARY/CONCLUSIONS

FIGURE 1.

WHAT IS A STICKER?

- STICKERS ARE CHARACTERIZED BY PROJECTILE TRAVELLING 0.5" TO 1.0", AFTER PROPELLANT IGNITION, THEN DECELERATING AND STOPPING

FIGURE 2

HOW DO WE CLEAR A STICKER ?

- TM9-2350-2170-10N FOR M109 AND M109A1 HOWITZERS, SEPT 74, PROVIDES INSTRUCTIONS FOR SAFELY CLEARING THE TUBE
- USUALLY NECESSARY TO FIRE A HIGHER ZONE PROPELLING CHARGE

FIGURE 3

STICKER HISTORY - ENGR/SERVICE TESTS

DATE	SYSTEM	QE MILS	TEMP	CHARGE	NO. TESTED	NO. STICKERS	REMARKS
68	M109/M107	300	70	M3Z1	10	1	SERVICE TEST OF XM483 PROJECTILE *
68	XM109A1-M107	300	70	M3Z1	3	3	SERVICE [illegible]STING XM109A1 (SHALLOW CONE)
68	XM109A1-M107	300	70	M3Z2	5	2	SERVICE TESTING XM109A1 (SHALLOW CONE)
70	XM109A1-M107	300	70	M3A1Z1	158	1	SERVICE TESTING XM109A1 (STEEP CONE)
70	XM109A1-M107	300	70	M3A1Z1	25	1	SERVICE TESTING XM109A1 (STEEP CONE)
FEB 74	M109A1-XM692	300	-65	M3A1Z1	50	2	DT II TESTING OF XM692 (STEEP CONE)
FEB 74	M109A1-XM692	300	-65	M3A1Z2	25	1	DT II TESTING OF XM692 (STEEP CONE)
FEB 75	M109A1-XM687	300	-25	XM164Z3	10	2	DT II TESTING OF XM687 - FIRED A TOTAL OF 261 RDS @ ZONE 3 FROM 2 TUBES (STEEP CONE GROOVED)

* NOT REPORTED ON AN EPR

FIGURE 4

STICKER HISTORY - STANDARDIZED SYSTEMS

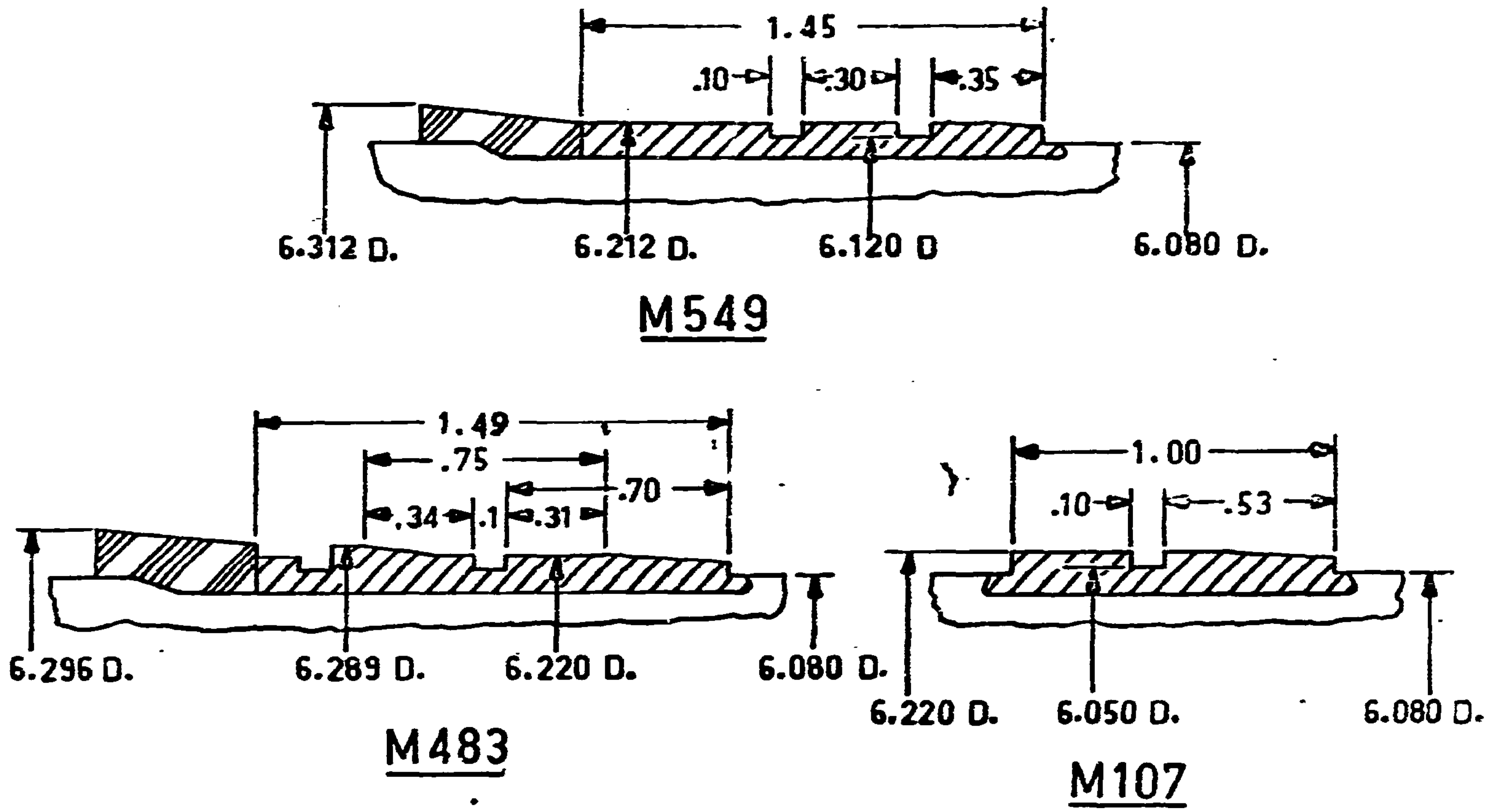
DATE	SYSTEM	QE MILS	TEMP	CHARGE	NO. TESTED	NO. STICKERS	REMARKS
SEP 68	M109-M107	300	70	M3Z1	10	1	DURING SERVICE TEST OF XM483
JUL 72	M109A1-M107	300	70	M3A1Z1	10	2	IPT OF LETTERKENNY M109A1 SYSTEM
		1150	70	M3A1Z1	10	5	10 FIRED M3A1 ZONE 1 600 MILS QE ZERO STICKERS
NOV 74	M109A1-M107	300	70	M3A1Z1	30	2	IPT OF BMY M109A1 SYSTEM
FEB 74	M109A1-M483	300	80	M3A1Z2	1	1	ALTERNATE FILL EVALUATION
FEB 74	M109A-M107	300	80	M3A1Z1	1	1	DURING DT II OF XM692

FIGURE 5

CHAMBER PRESSURES

M3A1	ZONE		
	1	2	3
M109	7500	9000	11500
M109A1	4900	5900	7800

FIGURE 6



ROTATING BAND CONFIGURATION

STANDARD 155MM SHELLS

Figure 7

BACKGROUND

DUGWAY - DTII TESTING XM687
16 NOV 74 - 19 FEB 75

NUMBER TESTED

TUBE SERIAL #	PROPELLANT ZONES					
	3	4	5	6	7	8
22927 *	201	20	35	30	25	10
22620	60	45	55	30	40	20

* TUBE THAT PRODUCED STICKERS. BOTH TUBES GROOVED AT DUGWAY 4 NOV 74

FIGURE 8

PROBLEM

DUGWAY - DTII TESTING XM687
10 FEB 1975
- TUBE SERIAL #22927

PROPELLANT	PROJ TEMP	M. V. MPS	PRESSURE
M3A1Z3	−25°F	—	9000
		268.3	8950
		267.5	9150
		268.2	9000
		—	9250
		—	8950
		—	9200
		—	8950
XM164Z3	−25°F	277.5	8750
			11500 *
		280.6	11100 **
			11700 *
		279.5	11200 **
		275.7	8850
		—	9150
		275.8	8800

* DENOTES STICKER
** BLOW OUT PRESSURE

FIGURE 9

SHORT TERM PROGRAM

OBJECTIVES

- DETERMINE CONDITIONS THAT PRODUCE HIGHEST FREQUENCY OF STICKERS
- DETERMINE FREQUENCY OF M483/M107 STICKERS ZONES 1, 2 & 3 UNDER WORST CONDITIONS
- EVALUATE MODIFICATIONS DESIGNED TO ELIMINATE ZONE 3, 2 STICKERS
- CHARACTERIZE PARAMETERS THAT INDUCE STICKERS AND MATHEMATICALLY MODEL

FIGURE 1C

FAULT TREE FOR STICKER INVESTIGATION OF 155MM; M483 PROJECTILE

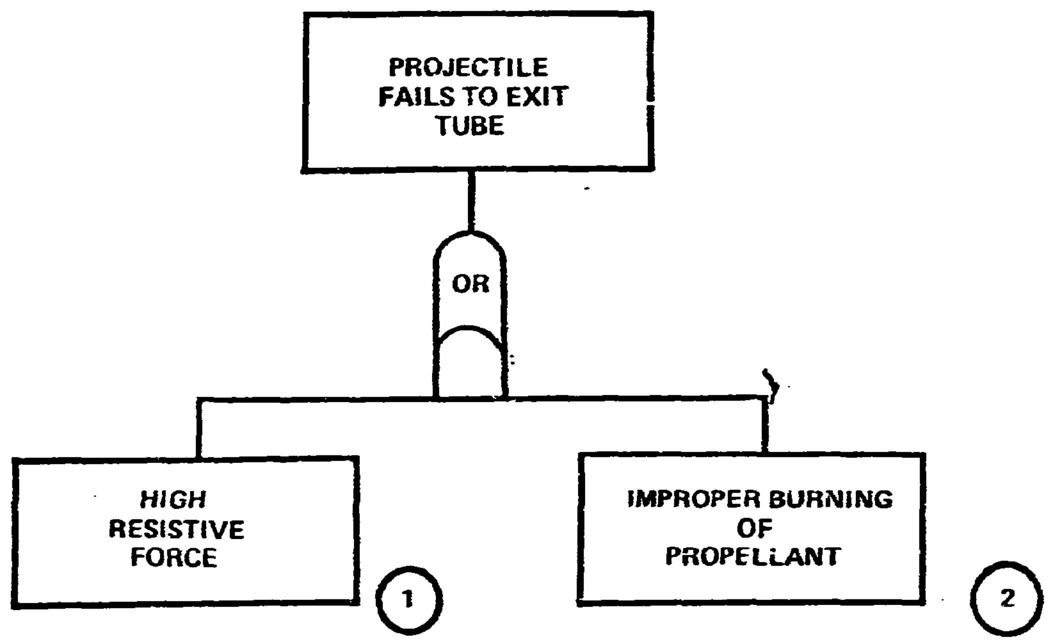


FIGURE 11

FACTORS EFFECTING STICKERS

	M483 SHORT TERM PROGRAM	155MM SYSTEM LONG TERM PROGRAM
PROJECTILE		
ROTATING BAND		
DIMENSIONS		X
MATERIAL		X
TEMPERATURE	X	X
SUPPORT STIFFNESS		X
METHOD OF ATTACHMENT		X
LUBRICATION	X	X
BOURRELET		X
PROPELLANT		
IGNITION DELAY TIME		X
RISE TIME	X	X
PEAK PRESSURE	X	X
TEMPERATURE	X	X
UNIFORMITY		X
WEAPON		
FORCING CONE ANGLE		X
GROOVING/HEAT CHECK	X	X
CONTAMINATION/COPPERING		X
WEAR	X	X
TUBE STIFFNESS		X
RAMMING		X

FIGURE 12

SCHEDULE

APRIL–MAY	JUNE	JULY	AUGUST
REPRODUCE DUGWAY INITIATE MEASUREMENT PHASE EVALUATE TUBE WEAR INITIATE MATH MODELS	DETERMINE EFFECT OF TEMPERATURE CONTINUE MEASUREMENT PROGRAM DETERMINE EFFECT OF SOLID LUBRICANT BAND FLOW	DETERMINE EFFECT OF PROP RISE TIME COMPLETE EFFECT OF TUBE WEAR DETERMINE EFFECT OF VOLUME REDUCER	DETERMINE RESISTIVE LOAD OF M483 FAMILY COMPLETE MATH MODELS
XM687 M483 M107 XM164 M3A1 M185 TUBE–NEW 10% WORN	M483 TEFLON O RINGS M3A1 M4A2 M185 TUBE 10% WORN	M483 M107 XM164 M10 MODIFIED CHG INERT PROP CHG VOLUME REDUCER M185 TUBE–50% WORN 5% WORN	XM687 XM692 XM718 M3A1 M185 TUBE–WORST TUBE

Figure 1-3

AGENCIES INVOLVED

- PICATINNY ARSENAL – PROGRAM COORDINATION & INTERIOR BALLISTICS
- WATERVLIET ARSENAL – PROJECTILE/CANNON INTERFACE
- BALLISTIC RESEARCH LABORATORY – INTERIOR BALLISTICS
- PROJECT MANAGER SELECTED AMMUNITION – OVERALL PROGRAM RESPONSIBILITY
- PROJECT MANAGER CAWS – PROP CHARGE – WEAPON INTERFACE
- RODMAN LABORATORY – PROJECTILE TUBE SEATING INTERFACE
- TECOM – DT/OT TESTING RESPONSIBILITY
- EDGEWOOD ARSENAL – XM687 PROJECTILE INTERFACE
- CONSULTANT
  - BATTELLE INSTITUTE – TUBE SURFACE ANALYSIS & COEFFICIENT OF FRICTION DETERMINATION

FIGURE 14

SERIES I - P. A. TEST RESULTS

TUBE NO	ZONE			
	1	2	3	
22657 (NONGROOVED) (NEW TUBE LESS THAN 100 RDS)	1/69		0/4	
21982 (GROOVED) (10% WORN TUBE 500 RDS)	2/2	11/17	1/3	M483 FAMILY
	1/2	0/4		M107

DUPLICATED ZONE 3 STICKER WITH GROOVED TUBE
DETERMINED TUBE CONDITION AFFECTS STICKER RATE

Figure 15

SERIES I - WATERVLIET

PUSH FORCE
(THOUSANDS OF LBS)

TUBE #22657

TEMPERATURE		M482	XM687	M107
-25°F	NONGROOVED	237–240	210	204–210
	GROOVED	288–314	264–282	246–261
	% DIFF	+25%	+30%	+22%
+145°F	NONGROOVED	258–264	–	228–240
	GROOVED	338–360	–	240–270
	% DIFF	+32%	–	+9%

TUBE #21982

-25°F	GROOVED	234	–	–
+145°F	GROOVED	324–336 *	–	252

* DATA QUESTIONED DUE TO RECORDING MALFUNCTION

FIGURE 16

POSSIBLE SYSTEM MODIFICATIONS

SHORT TERM

- SOLID LUBRICANT
- VOLUME REDUCER

LONG TERM

- NEW LOW ZONE CHARGE
- BAND MOD

FIGURE 17

	RISE TIME	PEAK
M10	7.0 M/SEC	5340
M3A1	18.0	4880
M3A1/W REDUCER	11.5	5980

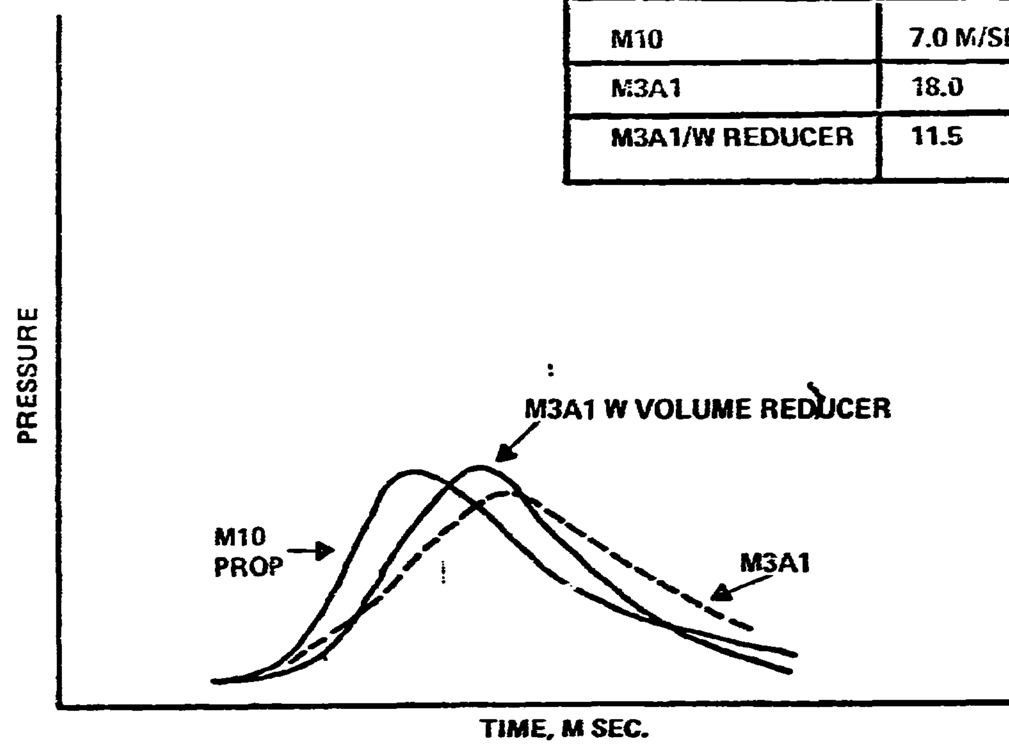
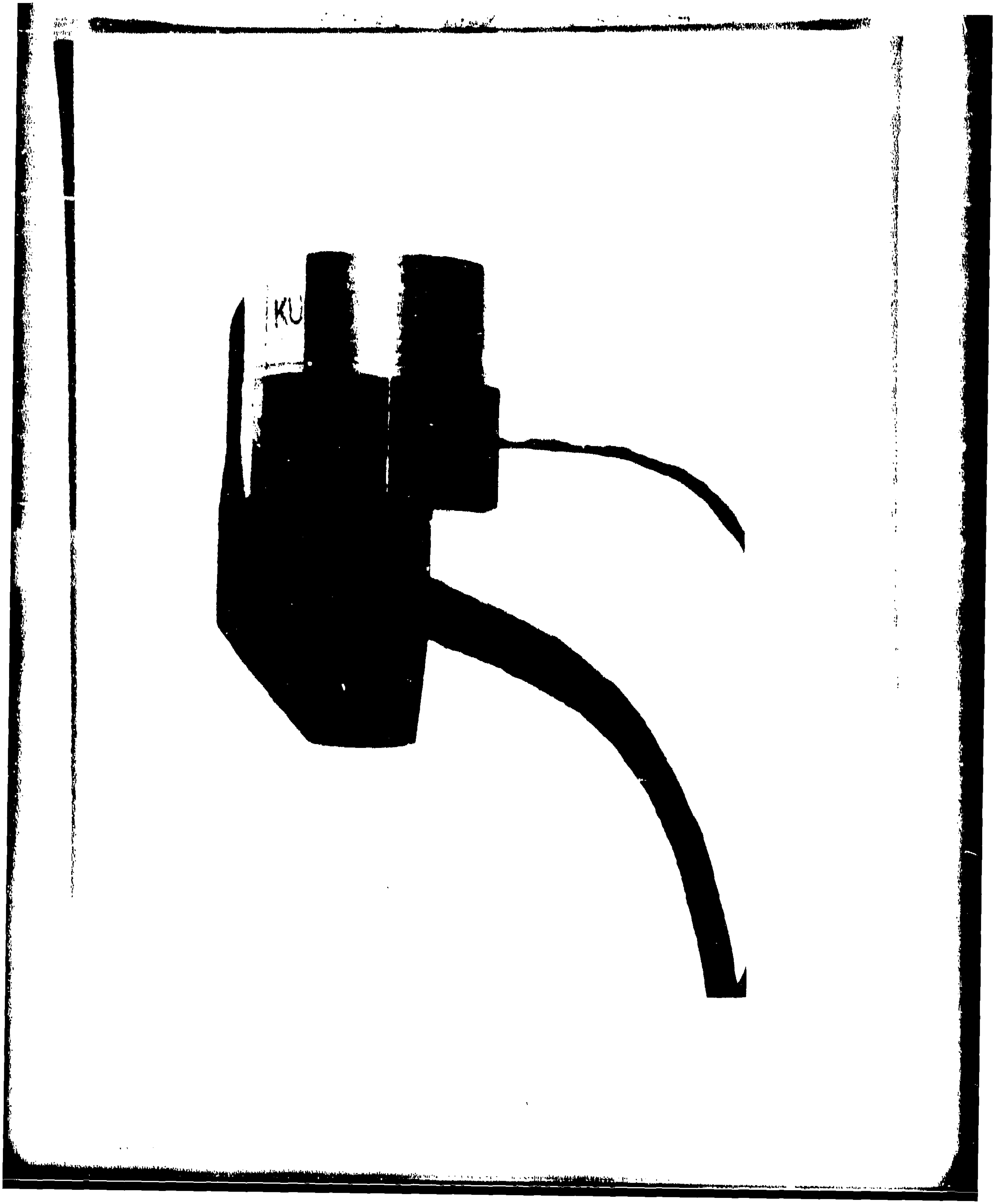


FIGURE 18



IN-BORE DATA VS SHELL-BAND CONSTRUCTION

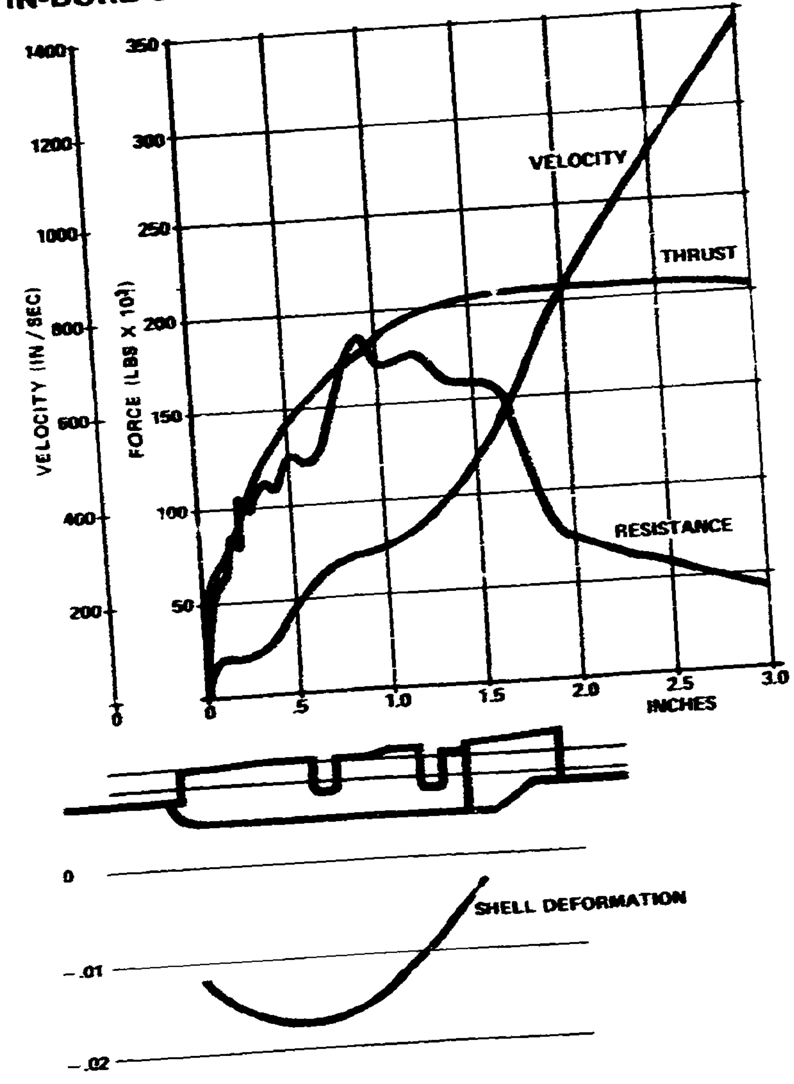


FIGURE 22

ENGINEERING SCIENCES DIVISION
FELTMAN RESEARCH LABORATORY
US ARMY PICATINNY ARSENAL

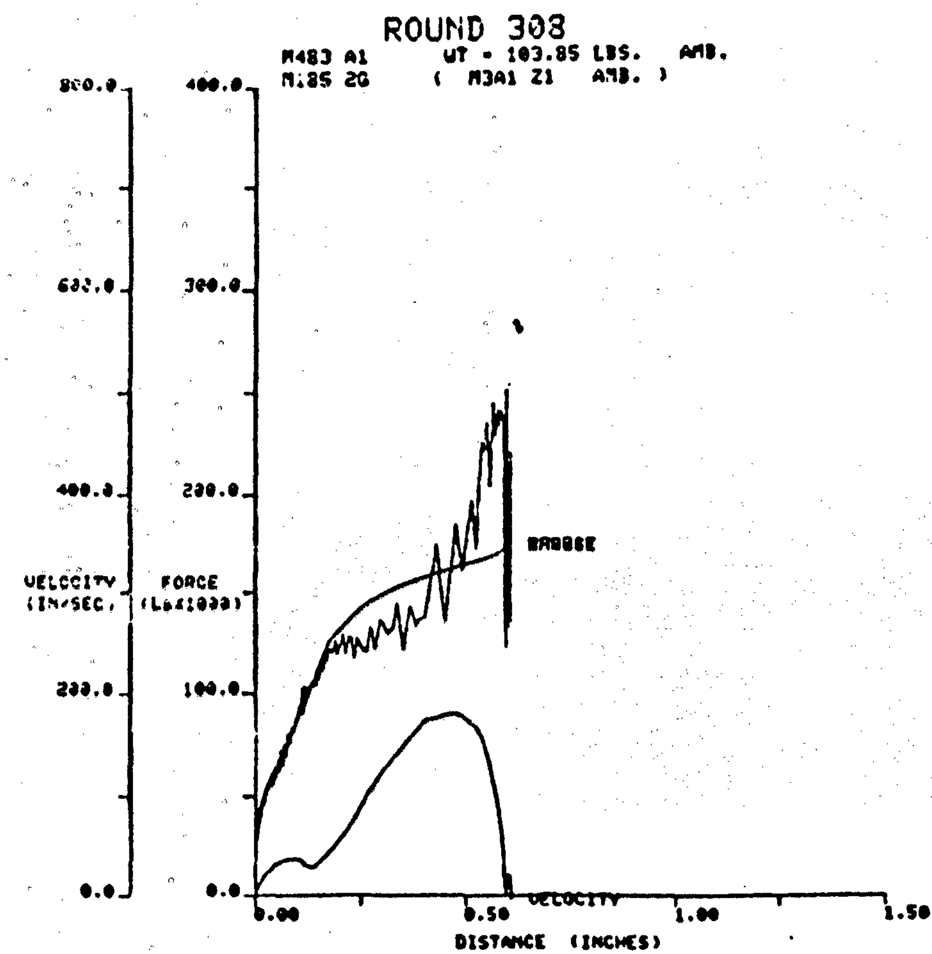


FIGURE 23

TYPICAL BAND RESISTANCE - TRAVEL CURVES

M483 SHORT TERM INVESTIGATION

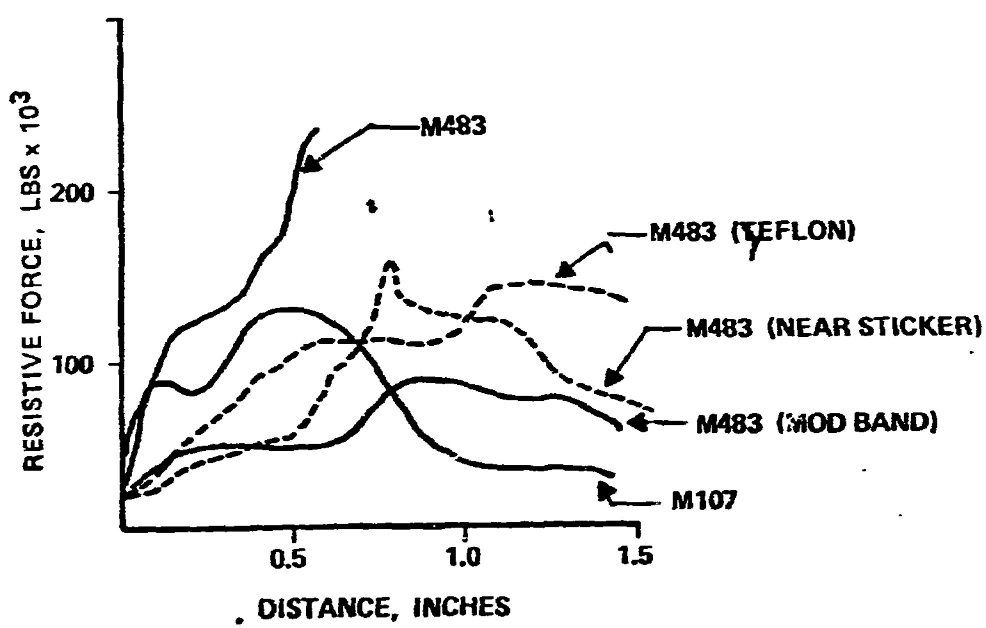


FIGURE 24

TYPICAL VELOCITY - DISTANCE CURVES

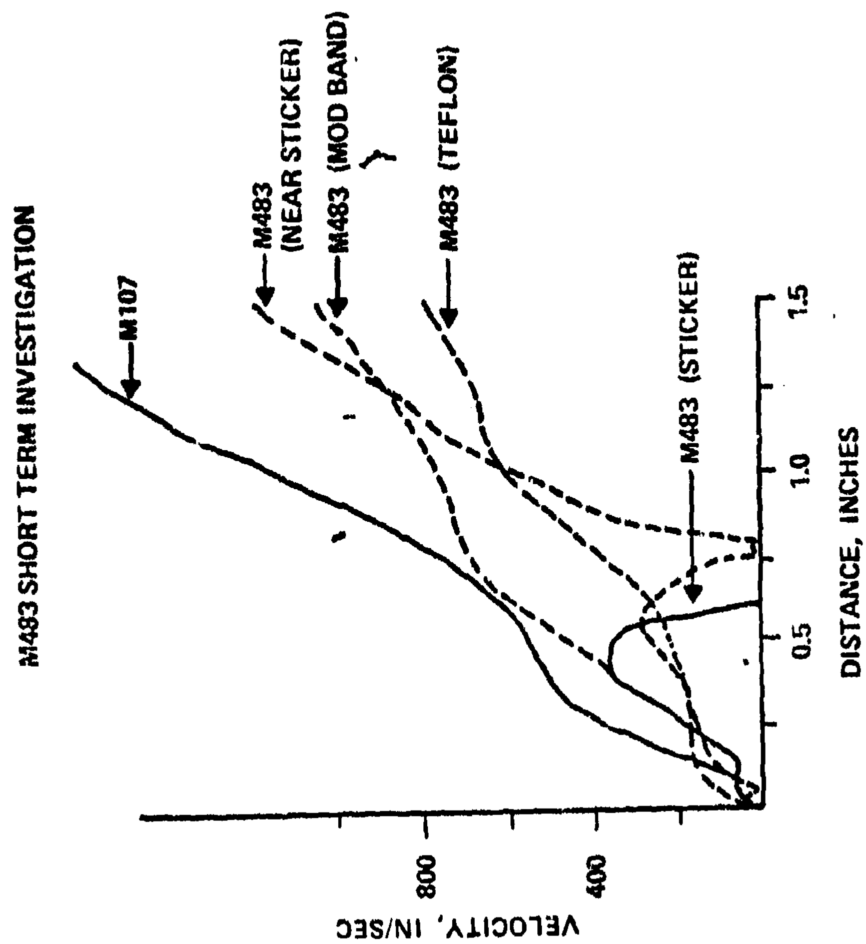


FIGURE 25

M483A1 STICKER INVESTIGATION

	TUBE: 22657 (2G)									TUBE: 21982 (4G)								
TEMP	+145°F			AMB			−65°F			AMB			−65°F			−40°F		
ZONE	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
M483A1	4	6	4	4/25	25	3	2/3	3	12	13/28	9/139	6			3		4/4	10
M167				3	3	4				1/3	22			5	3			
M483A1 TEFLON TUBE				10					10	6/32	155	3		1/4				1
M483A1 TEFLON RING				7							1			2/10	3		25	108

FIGURE 26

SUMMARY/CONCLUSIONS

- M483 PROJECTILE HAS HIGHER RESISTANCE THAN M107 PROJECTILE
- SOLID LUBRICANT REDUCES RESISTANCE
  - NO STICKERS OBTAINED AT
    - ZONE 3 (108 RDS AT −40°F)
    - ZONE 2 (155 RDS AT AMB)
    - ZONE 2 (25 RDS AT −40°F)
  - REDUCED STICKER RATES OBTAINED AT ZONE 1 AND AT −65°F ZONE 2
- MEASUREMENT PROGRAM IS CONTINUING TO DETERMINE EFFECT OF
  - LUBRICATION
  - TEMPERATURE
  - TUBE WEAR
  - PRESSURE RISE TIME
  - BAND RESISTANCE OF M483 FAMILY

Figure 27

155MM HARDWARE TO BE INVESTIGATED

PROJECTILE	PROPELLANT CHARGE	WEAPON
STOCKPILED	STOCKPILED	STOCKPILED
M107	M3A1	M114
M483	M4A2	M109
M549	M72	M109A1
M449A1		
M110 (CHEM)		
M116 (SMK)		
M454		
M485A2 (ILLUM)		
DEVELOPMENT	DEVELOPMENT	DEVELOPMENT
XM692	XM164	XM198
XM687		
XM718		
XM708		
XM694		

Figure 28

LONG TERM STICKER SCHEDULE

1ST YEAR	2ND YEAR	3RD YEAR
DETERMINE STICKER FREQUENCY OF STOCKPILE INITIATE STICKER-FALLBACK ANALYTICAL MEASUREMENTS, AND TEST PROGRAMS	EVALUATE CORRECTIVE ACTION ON STOCKPILE CONTINUE INVESTIGATION	DEMONSTRATE COMPLETE KNOWLEDGE OF STICKER FALLBACK PHENOMENA RECOMMENDATIONS FOR DEVELOPMENT ITEMS COMPLETE DOCUMENTATION AND REVISE TECH DATA

FIGURE 29

LONG TERM STICKER COST ESTIMATE

	1	2	3
P.A.	1100	1000	820
O.G.A.			
BRL	100	100	100
WATERVLIET	150	150	100
ROCK ISLAND	100	150	100
FRANKFORD	100	100	100
TECOM	150	100	100
CONTRACT			
BATTELLE INSTITUTE	50	50	–
LAWRENCE LIVERMORE	50	50	–
	1800	1700	1320
TOTAL		4820	

PROJECTILES, PROP CHG FURNISHED GFM

FY76 DOLLARS

INCLUDES COST OF MOD BAND PROJECTILES & DOWNLOADING 200 LINE STANDARD PROJECTILES

FIGURE 30

LONG TERM STICKER SCHEDULE

1ST YEAR

- DETERMINE STICKER-FALLBACK FREQUENCY OF STOCKPILE
- CHARACTERIZE VARIABLES OF AUTOMATIC RAMMING PROCESS
- CHARACTERIZE TUBE SURFACE CONDITIONS
- COMPLETE FOLLOWING MATH MODELS
  - RESISTIVE LOAD/MATERIAL FLOW
  - COEFFICIENT FRICTION/TUBE WEAR
  - BAND SHEAR/TUBE WEAR PROGRAM
- INITIATE BAND MATERIAL STUDY
- INITIATE MEASUREMENTS ON STOCKPILED & DEVELOPMENT PROJECTILES
- EVALUATE PROPELLANT UNIFORMITY
- INITIATE LOW ZONE PROPELLANT CHARGE MODIFICATION

FIGURE 7,1

SUMMARY/CONCLUSIONS

- STICKERS ARE COMPLEX SYSTEM PROBLEM
  PROJECTILE, PROPELLANT AND WEAPON
- EXTENT OF STICKER PROBLEM IS NOT KNOWN WITH MANY STOCK-PILED PROJECTILES
- ON BOARD ACCELEROMETERS PROVIDE ACCURATE AND VITAL INTERIOR BALLISTIC INFORMATION

Figure 32

RECOMMENDATIONS

- CONTINUE SHORT TERM M483 STICKER INVESTIGATION
- INITIATE LONG RANGE PROGRAM TO OBTAIN:
  - DATA ON EXPECTED STICKER RATES WITH CURRENT 155MM STOCKPILE OF PROJECTILES
  - OPTIONS FOR CORRECTIVE ACTION
- USER REQUIREMENTS SHOULD BE ESTABLISHED WITH REGARD TO STICKER ACCEPTABILITY

Figure 33